SUGGESTED

ELECTRIFICATION ADVISER

TRAINING OUTLINE

ELECTRIC

PUMP IRRIGATION

REA

Rural Electrification Administration U. S. Department of Agriculture

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INTRODUCTION

Soil, sun, air and water are essential for plant life. Although sunlight and air are generally beyond the farmer's influence he can use soil and water in such a way that he can exercise some control. At some time during the growing season, nearly every farmer experiences a need for rain. Irrigation is a dependable method by which the farmer can supplement natural rainfall at the time and in the amounts it is needed.

Irrigation is defined as the artificial application of water to soil for the purpose of supplying the water essential to plant growth. The source of water for irrigation purposes, its method of delivery and distribution, the type of land to be irrigated, and the crops to be grown under irrigation may vary considerably between areas to be irrigated, but regardless of any of these factors, its prime purpose is to provide increased crop production to such an extent that added income can be enjoyed by the irrigator and the farming area in general.

In many irrigation systems, and especially with sprinkler type irrigation systems, a pumping unit is required for their operation.. With the many advantages which an electric motor can provide as a power source for this pumping, irrigators are increasing their requests for electric service for their pump installations. Features which make electric motors especially desirable for pumping are their low initial cost, low cost of upkeep, high efficiency, compactness, their constant speed, dependability, long life, steady planning costs, and their labor-saving qualities. Members of cooperatives and power districts who desire to install an electric pump irrigation system usually desire to secure assistance in planning their system from their cooperative or power district. To assist its borrowers in rendering this valuable service, the following information has been prepared as a guide to be used by the Electrification Advisors.

PART I

FUNDAMENTALS OF ELECTRIC PUMP IRRIGATION

BASIC FUNDAMENTALS

There are certain basic fundamentals which electrification advisers should be familiar with when discussing electric pump irrigation. These fundamentals consist of units, equivalents, definitions and basic formulas.

The following discussion includes those which are most commonly used.

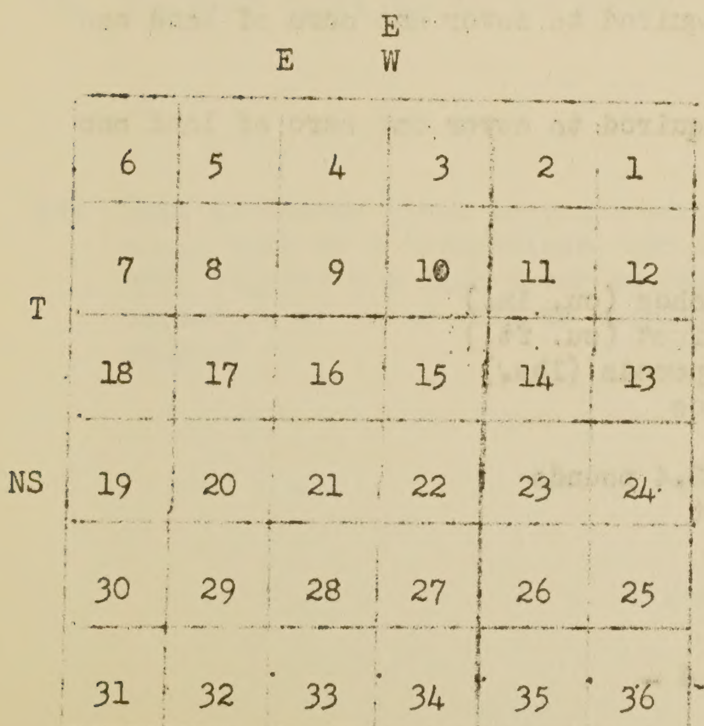
Lineal and Land Measurement

The determination of lengths and areas of land to be irrigated is one of the first steps involved in planning a pump irrigation system.

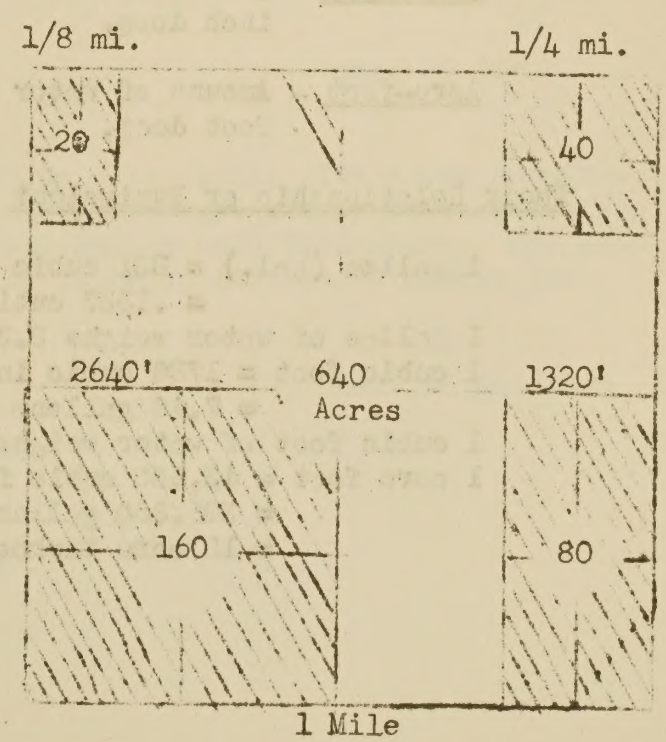
Most Common Units of Lengths Are:	Their Relationship or Equivalent:
Feet (ft.) - Rod - Chain - Mile (mi.)	$16\frac{1}{2}$ feet = 1 Rod 4 Rods or 66 Feet = 1 Chain 5,280 Ft. = 320 Rods = 80 Chains = 1 Mi.

Common Units of Area Are:	Their Relationship or Equivalent:
Square Feet (sq. ft.) - Square Rod - Square Mile - Acre (ac.) - Section - Quarter Section	43,5600 Square Feet = 1 Acre 1 Acre = 160 Square Rods 640 Acres = 1 Square Mile = 1 Section 160 Acres = 1 Quarter Section

Location of Sections in Township



Typical Sub-division of Standard Section



Volume and Weight

For one to determine the amount of water available or required for irrigation he must be acquainted with the terms and units of water used in discussing volumes of water.

The common units used in discussing volumes of water are:

Gallon - Cubic Inches - Cubic Foot - Acre Foot - Acre Inches

The common unit of weight is the:

Pound

Water in small tanks, cisterns, and sumps is usually measured in gallons.

Water in large tanks and small reservoirs is usually measured in cubic feet or gallons.

Water in large reservoirs is most commonly measured in acre-feet.

Water, as it is applied to land for irrigation, is measured in acre-inches or acre-feet.

Definitions:

Acre-inch - Amount of water required to cover one acre of land one inch deep.

Acre-foot - Amount of water required to cover one acre of land one foot deep.

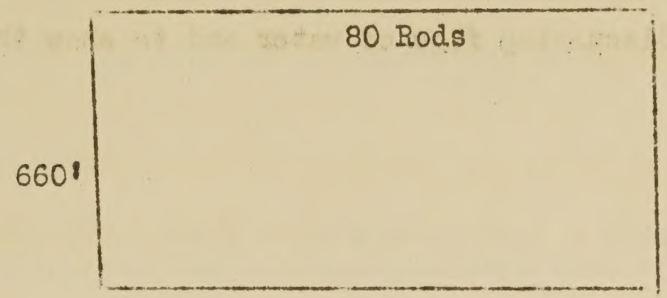
Their Relationship or Equivalent

1 gallon (gal.) = 231 cubic inches (cu. in.)
= .1337 cubic feet (cu. ft.)
1 gallon of water weighs 8.33 pounds (lbs.)
1 cubic foot = 1728 cubic inches
= 7.48 gallons
1 cubic foot of water weighs 62.4 pounds
1 acre foot = 43.560 cubic feet
= 325.850 gallons
= 12 acre inches

<u>Typical Problems</u>

A farmer is planning to irrigate a field which has the following dimensions:

Width 660 feet　　　　　　　　　　　　Length 80 Rods



(a) What is the length of the field in feet?

Ans. 1320 Feet

(b) How many rods wide is the field?

Ans. 40 Rods

(c) How many square rods are there in the field?

Ans. 3200 Sq. Rods

(d) How many acres are in the field?

Ans. 20 Acres

(e) This irrigator plans to plant alfalfa in this field. Its water requirements will be 6 irrigations each season and to get proper soil saturation will require a 4 inch water application during each irrigation. How many acre-feet of water will be required to irrigate this field during the season?

Ans. 40 Ac. Feet

Rates of Flow

In discussing, planning, or designing an irrigation system one immediately becomes involved in the rate of flow of water. This discussion is to clarify the various units used in discussing flow of water and to show their relationship to each other.

Units of flow are:

Gallons per minute (gpm) - Cubic feet per second (cfs) - Miners Inch (mi. in.)

Definitions:

1 gallon per minute - A rate of flow such that a 1 gallon measure would be filled each minute.

1 cubic foot per second - A rate of flow such that a measure of 1 cubic foot capacity would be filled each second. (Often called second-foot)

1 miner's inch - A rate of flow through an orifice of 1 square inch area under heads which vary locally.

Their relationship or equivalent:

1 gallon per minute = 0.00223 cubic feet per second
= 1440 gallons per day
1 cubic foot per second = 7.48 gallons per second
= 448.8 gallons per minute (approx. 450 gpm)
= .992 acre inch per hour (approx. 1.0 ac in/hr)
= 1.983 acre feet per day (24 hr) (approx. 2.0 ac ft/d.
= 40 miner's inches in Arizona, California, Montana and Oregon
= 50 miner's inches in Idaho, Kansas, Nebraska, Nevada, New Mexico, North Dakota, South Dakota and Utah.
= 38.4 miner's inches in Colorado
1 miner's inch = 11.25 gallons per minute when equivalent to 1/40 second foot
= 9 gallons per minute when equivalent to 1/50 second foot

Power

The driving force of a pump irrigation installation is its power unit. In an electric pump irrigation installation one must be familiar with power as a mechanical unit and also as an electrical unit.

Units of Power are:

Foot-pounds (ft. lbs.) - Horsepower (hp) - Horsepower-hours (hp. hr.)
Watts - Kilowatts (kw) - Kilowatt-hours (kw. hrs.) or (kwh)

Definitions:

When a given body is moved work is done in accomplishing that movement.

The unit of work is the foot-pound (ft. lbs.) and is accomplished when one pound of weight is moved a vertical distance of one foot.

If a time factor in which to accomplish certain work is added, the result is the necessary power.

Power is the time rate of doing work.

Horsepower is the mechanical unit of power.

Kilowatt is the electrical unit of power.

Equivalents:

1 horsepower = 33,000 foot pounds of work per minute
= 550 foot-pounds of work per second
= 746 watts or .746 kilowatts (approx. .750 kw)
1 Kilowatt = 1,000 watts
= 1.34 horsepower
1 horsepower-hour = 1 horsepower for 1 hour
1 kilowatt-hour = 1 kilowatt for 1 hour

Head and Pressure

To pump water for irrigation the pump operates against a head. This head consists of all the resistances encountered in raising the water to its point of use and that required to make it available for use in the desired manner. Heads consist of elevation which water is to be raised, the resistance due to friction in flow of water through pipes and pipe fittings, the added pressure required to operate a sprinkler system or other similar resistances which must be overcome by the pump.

Units used in discussing heads are:

Foot of Head   Pounds Per Square Inch (Pressure head)

Definitions:

Feet of Head is the pressure exerted by a column of water one foot high.
Pound Per Square Inch is pressure of one pound exerted on a square inch area.

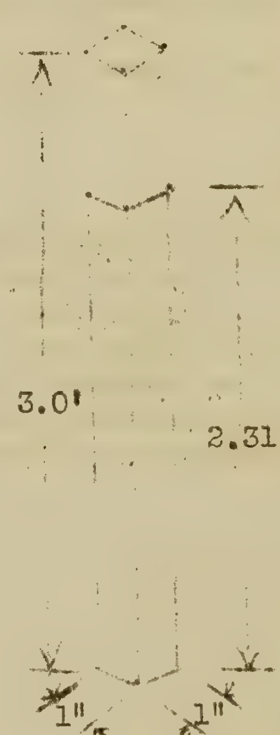
Equivalents:

1 foot of water head = 0.434 pounds per square inch
1 pound per square inch = 2.31 feet of water

This container will hold 0.433 pounds of water.

Pressure at this point is .434 lbs. per sq. in.

One pound of water will fill this container to a height of 2.31 feet.



Pressure at this point is 1 pound per sq. in.

Typical Problems

Rates of Flow

1. If a pump provides a discharge of 900 gallons per minute, what is the discharge in cubic feet per second? (b) Miner's inches? (c) Acre inches per hour?

Ans. (a) 2.0 cfs
(b) 80 or 100 Mi.In.
(c) 1.98 Ac.In./Hr.

2. If the pump in Problem 1 operates for 3 complete days (24 hours per day), how many acre feet of water will it have pumped?

Ans. 11.88 Ac. Ft.

3. If a farmer desires to apply 6 inches of water to a 10 acre field, how many hours of pumping will be required using the pump described in Problem 1?

Ans. 30.3 Hrs.

Power

1. What electrical power is required to operate a 5 horsepower motor?

Ans. 3.73 Kw.

2. If a 10 hp motor operates 5 hours, how many kilowatt-hours of energy did it use? (Do not consider efficiency.)

Ans. 37.3 Kwh.

Pressure and Head

1. How many pounds of pressure would be exerted at the base of a 1 square inch column of water if the water stood 10 feet high?

Ans. 4.34 lbs.

2. If an irrigation sprinkler system required a pressure of 40 pounds per square inch to operate, what equivalent feet of head would be required to make the system operate?

Ans. 92.4 Ft. Head

Pumping Head

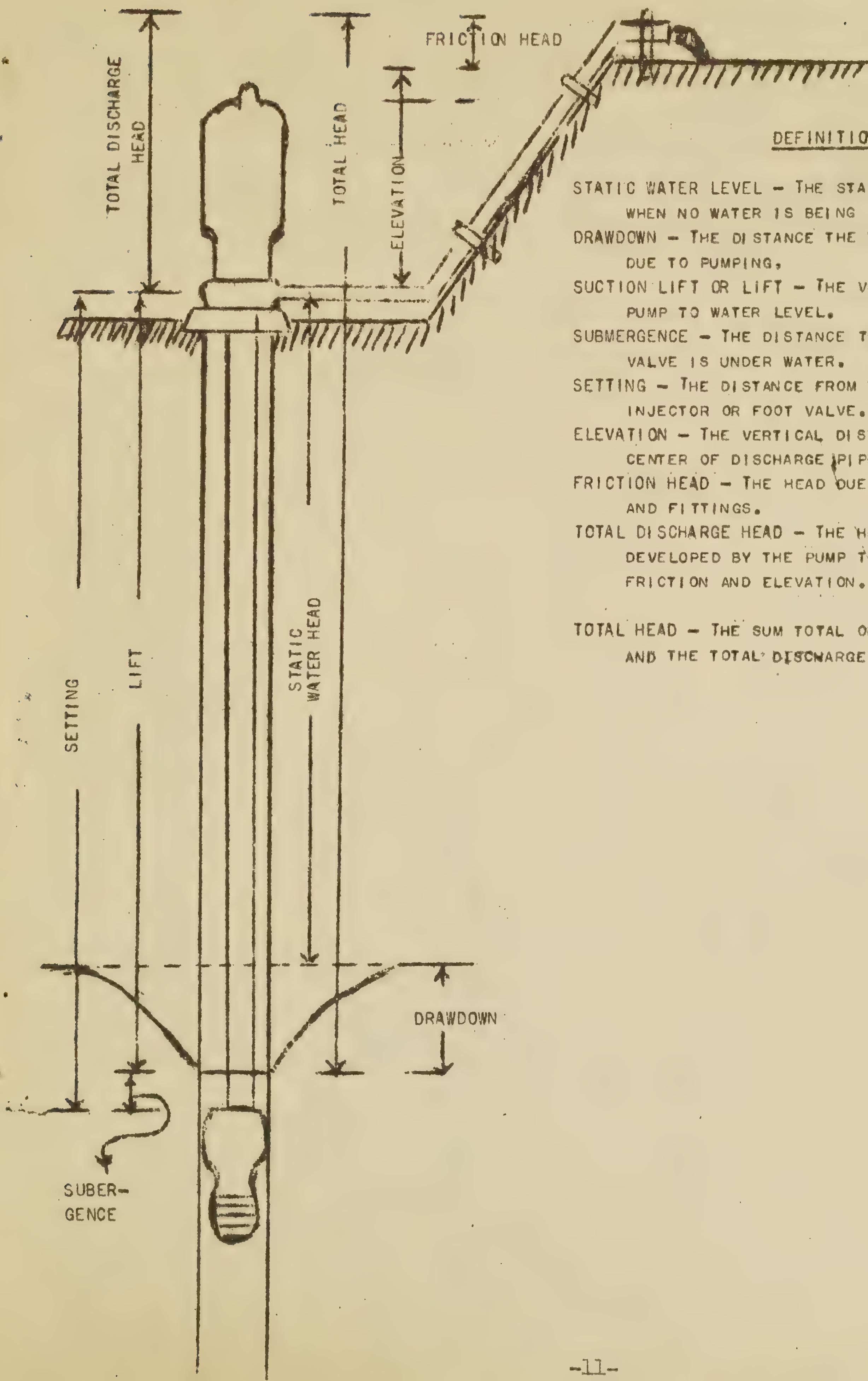
The sketches on the following pages illustrate the various pumping heads in two typical pumping systems. The first is of a deep well turbine pump installation with a free discharge at a higher level. The second of a centrifugal type pump installation operating a sprinkler system from a surface water supply.

SKETCH

DEEP WELL TURBINE – FREE DISCHARGE

ILLUSTRATES

PUMPING LIFTS AND HEADS



DEFINITIONS

STATIC WATER LEVEL – THE STATIONARY WATER LEVEL WHEN NO WATER IS BEING PUMPED.

DRAWDOWN – THE DISTANCE THE WATER LEVEL RECEDES DUE TO PUMPING,

SUCTION LIFT OR LIFT – THE VERTICAL DISTANCE FROM PUMP TO WATER LEVEL.

SUBMERGENCE – THE DISTANCE THE INJECTOR OR FOOT VALVE IS UNDER WATER.

SETTING – THE DISTANCE FROM THE PUMP TO THE INJECTOR OR FOOT VALVE.

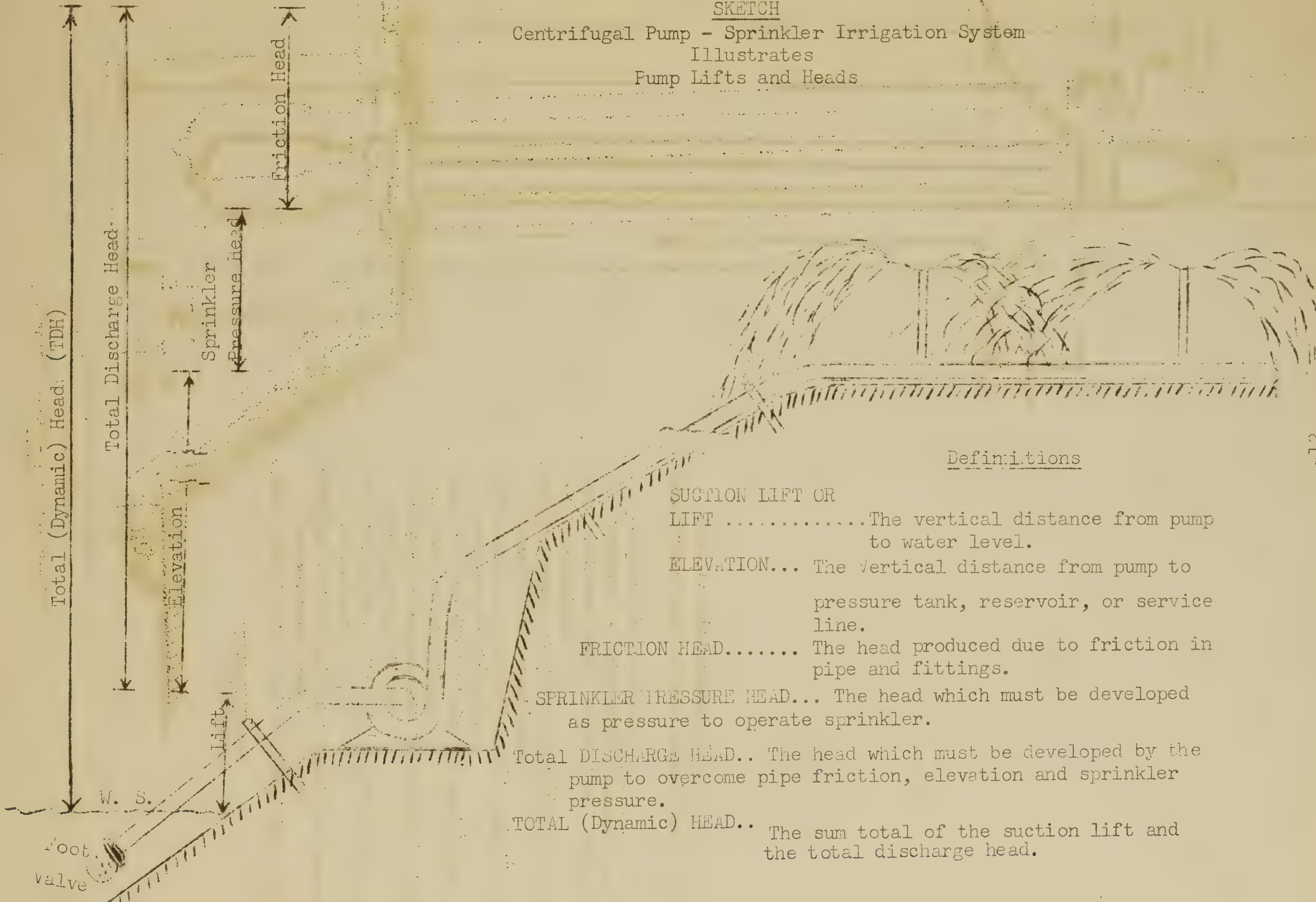
ELEVATION – THE VERTICAL DISTANCE FROM PUMP TO CENTER OF DISCHARGE PIPE.

FRICTION HEAD – THE HEAD DUE TO FRICTION IN PIPE AND FITTINGS.

TOTAL DISCHARGE HEAD – THE HEAD WHICH MUST BE DEVELOPED BY THE PUMP TO OVERCOME PIPE FRICTION AND ELEVATION.

TOTAL HEAD – THE SUM TOTAL OF THE LIFT AND THE TOTAL DISCHARGE HEAD.

SKETCH
Centrifugal Pump - Sprinkler Irrigation System
Illustrates
Pump Lifts and Heads



Definitions

SUCTION LIFT OR
LIFT ....The vertical distance from pump to water level.

ELEVATION... The vertical distance from pump to pressure tank, reservoir, or service line.

FRICTION HEAD....... The head produced due to friction in pipe and fittings.

SPRINKLER PRESSURE HEAD... The head which must be developed as pressure to operate sprinkler.

Total DISCHARGE HEAD.. The head which must be developed by the pump to overcome pipe friction, elevation and sprinkler pressure.

TOTAL (Dynamic) HEAD.. The sum total of the suction lift and the total discharge head.

Friction Losses In A Pumping System

The friction losses shown in the following table can be used for estimating friction head on surface irrigation installations. To find the friction head of a sprinkler irrigation system is much more complicated and will require additional tables.

DEFINITION:

Friction Loss - The head lost due to friction in pipes and fittings.

TABLE

Friction Loss per 100 Feet of Common Used Pipe and Loss Due to Fittings.

Gallons Per Minute	Diameter of Pipe 1/ 4 - in.	5 - in.	6 - in.	8 - in.	10 - in.
	Friction Head in Feet				
400	15.82	5.33	2.21	0.56	0.[illegible]1
450	19.75	6.65	2.74	0.64	0.21
500	24.08	8.12	3.26	0.81	0.28
750		17.22	7.00	1.74	0.59
1000			12.04	3.02	1.01
1250			18.20	4.45	1.51
1500				6.27	2.09
2000				10.71	3.50
Friction Losses From Pipe Fittings in Terms of Equivalent Lengths of Pipe					
Gate Valve	3.44	4.57	5.72	8.10	10.70
Medium Sweep Elbow	5.77	7.68	9.61	13.60	17.97
Standard Elbow	9.22	12.20	15.30	21.71	28.70

1/ Friction losses computed from Williams and Hazen tables for ordinary pipe.

Typical Problems

Determining Pumping Heads:

1. After Jack Jones drilled his well, he found that static water level below the center of pump discharge was 76 feet. He planned to use a deep well turbine pump. When pumping 800 gallons per minute, the drawdown was 18 feet. The pump was discharging the water into a discharge basin at the pump. The well was 210 feet deep and the setting was at 120 feet. What head would the pump operate against in securing the 800 gallons per minute discharge from the well?

Ans.: 94.0 Feet of Head

2. Bert Smith was preparing to irrigate an 80 acre plot above the river by using a centrifugal pump. The lift from the water level in the river to center of pump intake was 10 feet. Suction pipe was 15 feet long. He had to pipe the water up the river bank a distance of 959 feet. The elevation above pump to point of discharge was 84 feet. He was able to get by with the use of 3 Medium Sweep elbows. He was planning a discharge of 1,000 gallons per minute, and was to use an 8 inch pipe and fittings. What would be the total dynamic head of his installation?

Ans.: 124.2 Feet

Water Horsepower

The water horsepower is defined as the power theoretically required to lift a given quantity of water to a certain height in a specified time. In irrigation pumping it may be termed the output of the pump installation or a measurement of what is being accomplished.

The Basic Formula for Water Horsepower is:

When discharge is in gallons per minute:

$$\text{Water Horsepower} = \frac{\text{Discharge in GPM} \times \text{Weight/Gallon} \times \text{Total Head in Feet}}{\text{Foot pounds/Minute/Horsepower}}$$

Since water weighs 8.3 pounds per gallon and one horsepower is equal to 33,000 foot pounds per minute we can write the formula:

$$\text{Water Horsepower} = \frac{\text{Discharge in GPM} \times 8.3 \times \text{Total Head}}{33{,}000}$$

Since $\frac{8.3}{33{,}000} = 1/3960$ we can write:

$$\underset{\text{(Theoretical)}}{\text{Water Horsepower}} = \frac{\text{Discharge in GPM} \times \text{Total Head}}{3960}$$

When discharge is in cubic feet per second:

$$\text{Water Horsepower} = \frac{\text{Discharge in cfs} \times \text{weight/cubic ft.} \times \text{Total Head in Ft.}}{\text{Foot pounds/second/horsepower}}$$

Since water weighs 62.5 pounds per cubic foot and one horsepower is equal to 550 foot-pounds per second we can write the formula:

$$\text{Water Horsepower} = \frac{\text{Discharge in cfs} \times 62.5 \times \text{Total Head}}{550}$$

Since $\frac{62.5}{550} = 1/8.8$ we can write:

$$\underset{\text{(Theoretical)}}{\text{Water Horsepower}} = \frac{\text{Discharge in cfs} \times \text{Total Head}}{8.8}$$

Power Input to Motor

The energy consumed by an irrigation pump is measured by a standard kilowatt-hour meter. It is possible to determine the power input into an irrigation motor by timing the revolutions of the disc of the meter and applying the following equation:

Equation:

$$kw = \frac{R \times K \times 3.6}{t}$$

where,

R = number of revolutions of a disc in t seconds.

K = disc constant - watt-hours per revolution of the disc (usually found on name plate of meter) (K^h)

3.6 = factor which is equal to 3,600, the number of seconds in an hour, divided by 1,000, the number of watts in a kilowatt.

The horsepower input can be determined by the following conversion:

HP = Kilowatt x 1.34

Efficiencies

Of utmost importance to the irrigator is the efficiency of his pumping equipment. The economical operation of his irrigation system will depend upon the efficiency of his equipment. Efficiency is actually a ratio of the work accomplished to the work expended or more simply the output to the input. In a pumping installation one must consider the motor efficiency, the pump efficiency and the overall efficiency. These efficiencies are more fully expressed by the following equations:

Equations:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

$$\text{Overall efficiency} = \frac{\text{Water Horsepower}}{\text{Horsepower input to motor}}$$

$$\text{Motor efficiency} = \frac{\text{Brake horsepower of motor}}{\text{Horsepower input to motor}}$$

$$\text{Pump efficiency} = \frac{\text{Water Horsepower}}{\text{Brake horsepower of motor}}$$

Overall efficiency = Motor efficiency x pump efficiency (wire to water)

Note: To express efficiency as a percent, multiply by 100.

Typical Problems

Water Horsepower

1. If a pump discharges 2 second feet (cu. ft./sec.) of water against a head of 88 feet, what water horsepower is it developing?

Ans.: 20 H.P.

2. If a pump discharges 990 gallons per minute and is operating against a head of 120 feet, what water horsepower is being developed?

Ans.: 30 H.P.

Power Input to Motor

1. If 20 KW is the measured input to a motor, what is the horsepower input?

Ans.: 26.8 H.P.

2. If in checking an irrigation pump meter you find that the disc revolves 10 times in 48 seconds and the disc constant taken from the meter is $K^h = 24$, what horsepower input should you tell the member that his motor is using?

Ans.: 24.12 H.P.

Efficiencies

1. By checking a meter and making the necessary calculations it was found that the input to an irrigation pump motor was 50 horsepower. By measuring the pump discharge and lift, 30 water horsepower is found. What is the overall (wire to water) efficiency of the installation?

Ans.: 60% Eff.

2. If motor efficiency is 85 percent and pump efficiency is 70 percent, what is the overall efficiency?

Ans.: 59.5% Eff.

Motor Horsepower

The size of motor required to operate a pump under a given set of conditions is one of the essentials in the design of an electric pump irrigation system. The installation of the proper size motor is important to the irrigator and the power supplier. To determine the size of motor, data is needed on the rate of discharge, the total head under which the pump is to operate, and the efficiency of the pump. Equations used for this computation are provided below.

Definitions:

There are two basic horsepower definitions as they apply to motors:

The Rated Horsepower of a motor is the horsepower the motor will develop when operating at full load.

The Brake Horsepower is the actual horsepower being delivered by the shaft.

The horsepower output of a motor is the horsepower input to the motor multiplied by the efficiency of the motor.

Equations:

Two basic equations to determine brake horsepower required are as follows:

$$HP = \frac{\text{GPM x Head (in feet)}}{\text{3960 x Pump Efficiency}} \quad \text{or} \quad \frac{\text{Cubic Feet per Second x Head (in feet)}}{\text{8.8 x Pump Efficiency}}$$

Note: When brake horsepower requirements have been determined then select an electric motor with a rated horsepower equivalent to or a size larger.

Listed are motors manufactured with rated horsepower between 5 hp and 200 hp.

5-7½-10-15-20-25-30-40-50-60-75-100-125-160-175-200

Computation of Head - Discharge - Efficiency

By various algebraic variations of the basic equation used to determine the motor size (Motor Horsepower) it is possible to determine Total Pump Head, Discharge, or Pump Efficiency. This is providing that three of the four units (Brake Horsepower, Total Head, Discharge, Efficiency) are known.

Basic Brake Horsepower Equation

Discharge in Gallons Per Minute

$$HP = \frac{GPM \times \text{Total Head}}{3960 \times \text{Pump Efficiency}}$$

Discharge in Cubic Foot Per Second

$$HP = \frac{c.f.s. \times \text{Total Head}}{8.8 \times \text{Pump Efficiency}}$$

Discharge

$$GPM = \frac{HP \times 3960 \times \text{Pump Efficiency}}{\text{Total Head}}$$

$$CFS = \frac{HP \times 8.8 \times \text{Pump Efficiency}}{\text{Total Head}}$$

Total Head

$$TH = \frac{HP \times 2960 \times \text{Pump Efficiency}}{GPM}$$

$$TH = \frac{HP \times 8.8 \times \text{Pump Efficiency}}{CFS}$$

Pump Efficiency

$$EFF = \frac{GPM \times \text{Total Head}}{3960 \times HP}$$

$$EFF = \frac{CFS \times \text{Total Head}}{8.8 \times HP}$$

Data obtained by use of the above equations can also be obtained by use of the following table. The computations in the table are based on a 50 percent efficiency. They can be corrected to apply to other efficiencies.

HORSEPOWER REQUIRED TO PUMP DIFFERENT QUANTITIES OF WATER AGAINST TOTAL HEADS OF 10 TO 200 FEET

DISCHARGE		HORSEPOWER REQUIRED FOR LIFTS OF –													
GALLONS PER MINUTE	CUBIC FEET PER SECOND	10 FEET	20 FEET	30 FEET	40 FEET	50 FEET	60 FEET	70 FEET	80 FEET	90 FEET	100 FEET	125 FEET	150 FEET	175 FEET	200 FEET
25	0.056	0.126	0.253	0.379	0.505	0.631	0.758	0.884	1.01	1.14	1.26	1.58	1.89	2.21	2.52
50	.111	.253	.505	.758	1.01	1.26	1.52	1.77	2.02	2.27	2.53	3.16	3.79	4.42	5.05
100	.22	.50	1.01	1.52	2.02	2.53	3.03	3.54	4.04	4.55	5.05	6.31	7.58	8.84	10.10
150	.33	.76	1.52	2.27	3.03	3.79	4.55	5.30	6.06	6.82	7.58	9.47	11.36	13.26	15.15
200	.45	1.01	2.02	3.03	4.04	5.05	6.06	7.07	8.08	9.09	10.10	12.62	15.15	17.68	20.20
250	.56	1.26	2.53	3.79	5.05	6.31	7.58	8.84	10.10	11.36	12.63	15.78	18.94	22.10	25.25
300	.67	1.52	3.03	4.55	6.06	7.58	9.09	10.61	12.12	13.64	15.15	18.93	22.73	26.52	30.30
350	.78	1.77	3.54	5.30	7.07	8.84	10.61	12.37	14.14	15.91	17.68	22.09	26.52	30.93	35.35
400	.89	2.02	4.04	6.06	8.08	10.10	12.12	14.14	16.16	18.18	20.20	25.24	30.30	35.35	40.40
450	1.00	2.27	4.55	6.82	9.09	11.36	13.64	15.91	18.18	20.45	22.73	28.40	34.09	39.77	45.45
500	1.11	2.53	5.05	7.58	10.10	12.63	15.15	17.68	20.20	22.73	25.25	31.55	37.88	44.19	50.51
600	1.34	3.03	6.06	9.09	12.12	15.15	18.18	21.21	24.24	27.27	30.30	37.86	45.45	53.03	60.61
700	1.56	3.54	7.07	10.61	14.14	17.68	21.21	24.75	28.28	31.82	35.35	43.17	53.03	61.87	70.71
800	1.78	4.04	8.08	12.12	16.16	20.20	24.24	28.28	32.32	36.36	40.40	50.49	60.61	70.71	80.81
900	2.01	4.55	9.09	13.64	18.18	22.73	27.27	31.82	36.36	40.91	45.45	56.79	68.18	79.55	90.91
1,000	2.23	5.05	10.10	15.15	20.20	25.25	30.30	35.35	40.40	45.45	50.51	63.10	75.76	88.38	101.01
1,250	2.78	6.31	12.63	18.94	25.25	31.57	37.88	44.19	50.50	56.82	63.13	78.88	94.70	110.48	126.26
1,500	3.34	7.58	15.15	22.73	30.30	37.88	45.45	53.03	60.61	68.18	75.76	94.55	113.64	132.58	151.52

EFFICIENCY OF PUMPING PLANT 50 PERCENT. USE FOR PRELIMINARY ESTIMATES ONLY.

ADAPTED FROM U. S. DEPARTMENT OF AGRICULTURE FARMERS' BULLETIN 1404, PUMPING FROM WELLS FOR IRRIGATION.

EQUATION USED IN PREPARING TABLE:

$$HP = \frac{\text{GPM} \times \text{HEAD (IN FEET)}}{3960 \times \text{PUMP EFFICIENCY}} = \frac{\text{CFS} \times \text{HEAD (IN FEET)}}{8.8 \times \text{PUMP EFFICIENCY}}$$

Typical Problems

Computation of Horsepower - check results by use of table

1. Bert Cooke asked the electrification adviser what size electric motor would be needed to irrigate from his well. The well had been tested and was capable of a discharge of 924 gallons per minute at a lift of 60 feet. The pump dealer had assured Mr. Cooke that the pump was tested and would operate at 70.0 percent efficiency. Under these conditions what size motor did the adviser tell Mr. Cooke he would need?

Ans.: 20 H.P.

2. Jack Jones needed a flow of 3 second feet to pump irrigate his farm. His plan was to pump from the large river which ran by his farm. At the point where he was going to install his pump he found that the total head which his centrifugal pump was to operate against was 50 feet. The efficiency of the pump operating under these conditions was 57 percent. What size electric motor should Mr. Jones have installed?

Ans.: 30 H.P.

3. A farmer is ready to install a sprinkler irrigation system on his farm. The engineer installing the system secured the following data as to his requirements.

Thirty sprinkler jets requiring 8 gpm were to be used.
The lift from water to pump would be 15 feet.
Elevation from pump to highest point of land to be irrigated was 26 feet.
Friction head loss would be 14.7 feet.
System was to operate at 30 pounds per square inch pressure.
Centrifugal pump on system was 60 percent efficient.

What was the total head? (TDH)

What size motor would be required on system?

Ans.: (a) 125 Ft.

(b) 15 H.P.

Discharge

1. What will the rate of pump discharge be if a farmer is using a 40 horsepower motor on a pump that is 50 percent efficient against 100 feet of head?

Ans.: GPM 792
CFS 1.76

2. A farmer has been using a 15 hp motor on a feed grinder and wants to use the same motor on his sprinkler irrigation system. His system requires a minimum discharge of 300 gallons per minute against a total head of 100 feet. The efficiency is 60 percent. Can he use the same motor for both jobs?

Ans.: Same motor can be used.

Head

1. A 30 horsepower motor, operating a pump with a 60 percent efficiency, is providing sprinkler irrigation system with a discharge of 600 gallons per minute. What feet of head is the pump operating against?

Ans.: 118.8 Feet.

Kilowatt-Hour Consumption

The kilowatt-hour consumption of a pump irrigation installation is based upon the brake horsepower requirements of the installation, its hours of operation, and the efficiency of the electric motor. The brake horsepower requirements can be converted to kilowatts by use of the following equation:

$$\text{Kilowatts} = \frac{\text{Brake Horsepower} \times .746}{\text{Motor Efficiency}}$$

Kilowatt-hours can be determined by multiplying the kilowatts by hours of operation.

$$\text{Kilowatt-Hours} = \text{Kilowatts} \times \text{Hours Operation}$$

Approximate Motor Efficiencies

5 to 10 horsepower	82 percent
10 to 30 "	85 "
30 to 100 "	89 "
100 "	90 "
100 to 500 "	92 "

There are several algebraic equations that can be used to determine kilowatt-hour consumption for pumping water. Those most commonly used are as follows:

To determine kilowatt-hour consumption based on acre feet of water pumped:

$$\text{Kilowatt-hours} = 1.024 \times \frac{\text{Total Head}}{\text{Overall Efficiency}}$$

To determine kilowatt consumption per hour operation:

$$\text{Kilowatt-hours} = \frac{.000189 \times \text{GPM} \times \text{Total Head}}{\text{Overall Efficiency}}$$

To determine kilowatt-hours per 1,000 gallons (not GPM) for each foot of head:

$$\text{Kilowatt-hours} = \frac{.00315}{\text{Overall Efficiency}}$$

Kilowatt-hour Consumption

1. A pump requires 30 horsepower. The motor operates at 90 percent efficiency. What is the kilowatt requirement or demand of the installation?

Ans.: 24.8 KW

2. If the pump in Problem 1 operates for 2,500 hours during the season, how many kilowatt-hours of electricity does it consume?

Ans.: 62,000 KWH

3. If a pump is required to pump 1 acre foot of water against 120 feet of total head, pump efficiency is 66 percent, and motor efficiency 91 percent, (a) what is the overall efficiency of the installation? (b) How many kilowatt-hours will be required to pump the 1 acre foot of water?

Ans.: (a) 60%
(b) 204.67 KWH

4. If an irrigator had a 25 acre field which had an average water requirement of 5 acre feet of water per acre during the season, how many kilowatt-hours would be consumed during the season if he was pumping with the installation described in Problem 3?

Ans.: 25,750 KWH

PART II

P U M P I R R I G A T I O N E F F I C I E N C I E S

A N D

H O W T H E Y A R E D E T E R M I N E D

PUMP EFFICIENCIES

The definition of pump efficiency has been explained as the percentage ratio of what is being accomplished for the power or money that is being put into the installation. We could more simply say the output divided by the input.

One of the primary objectives of research by manufacturers of pump equipment has been to determine ways in which the operating efficiencies of their pumps could be increased. During recent years tremendous improvements have been made in this respect. But regardless of all the research and improvements, it is of little advantage to the irrigator unless the actual field efficiency of his pumping plant is as it should be.

The efficiency of a pump irrigation plant can be obtained only if the following is carried out.

A. That he has had installed a pumping unit designed to fit his actual pumping conditions.

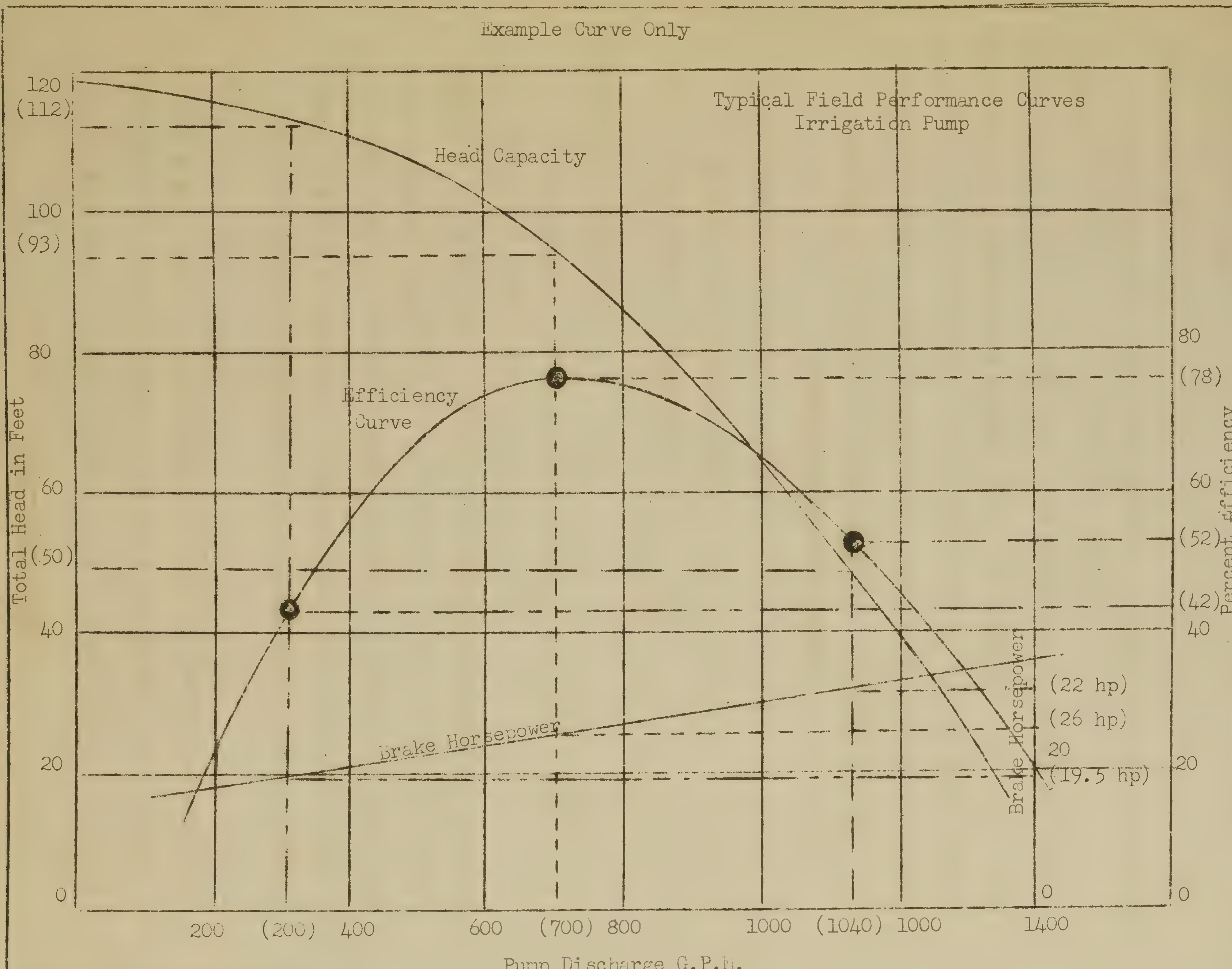
B. That his overall plant design is well engineered.

C. Proper and adequate maintenance.

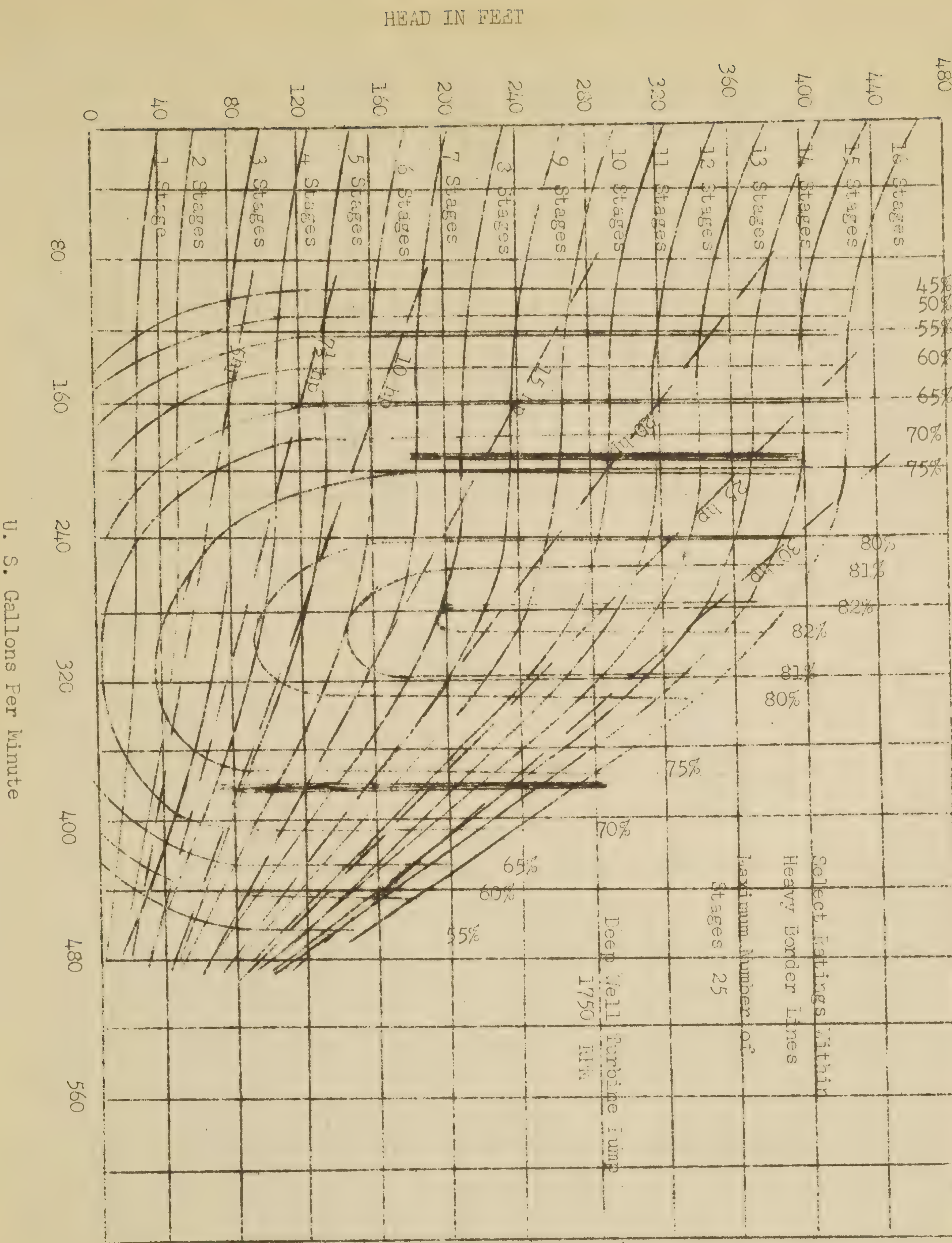
Pump Characteristic Curves

Each pump manufactured is designed to operate at maximum efficiency under specific conditions. These conditions are shown on its characteristic curve which has been prepared from actual laboratory tests. These curves show the efficiency of the pump under various operating conditions. It is felt that those working in electric pump irrigation should understand and be able to interpret data from these characteristic curves.

We have included for discussion purposes the following two examples of typical pump characteristic curves. Although these curves may vary in design basically, they provide the same data and are used for the same purpose.

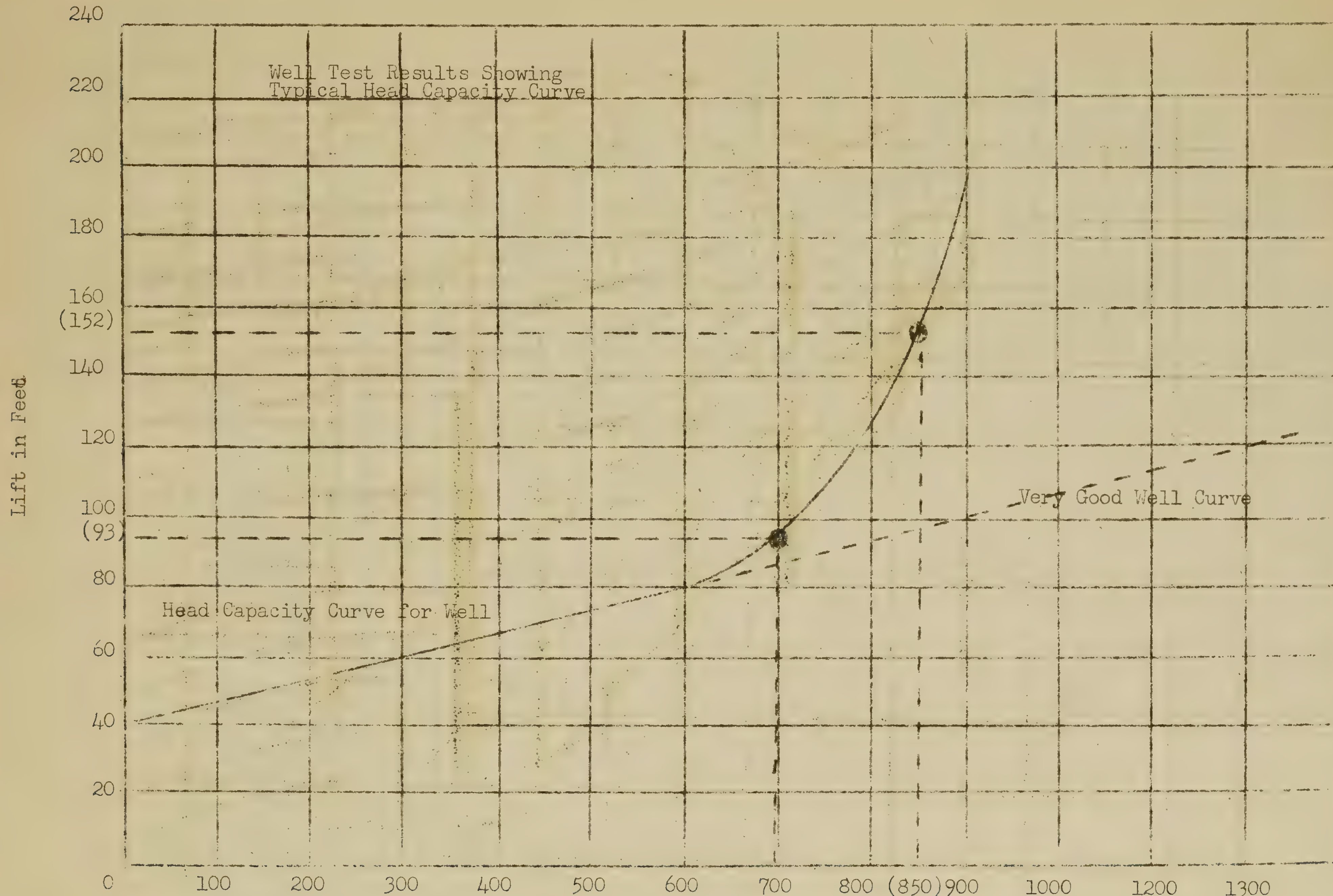


Example Curve Only
Typical Field Performance Curves
Irrigation Pump
Head Capacity
Efficiency
Curve
Brake Horsepower
Brake Horsepower
Total Head in Feet
120
(112)
100
(93)
80
60
(50)
40
20
0
Percent Efficiency
80
(78)
60
(52)
(42)
40
20
0
(22 hp)
(26 hp)
20
(19.5 hp)
0
200
(200)
400
600
(700)
800
1000
(1040)
1000
1400
Pump Discharge G.P.M.



HEAD IN FEET
0
40
80
120
160
200
240
280
320
360
400
440
480
1 Stage
2 Stages
3 Stages
4 Stages
5 Stages
6 Stages
7 Stages
8 Stages
9 Stages
10 Stages
11 Stages
12 Stages
13 Stages
14 Stages
15 Stages
16 Stages
45%
50%
55%
60%
65%
70%
75%
80%
81%
82%
82%
81%
80%
75%
70%
65%
60%
55%
7½ hp
10 hp
15 hp
Select Ratings Within Heavy Border Lines
Maximum Number of Stages 25
Deep Well Turbine Pump 1750 RPM
80
160
240
320
400
480
560
U. S. Gallons Per Minute

Example Curve Only



Efficiencies Effect on Pumping Costs

Efficiencies are probably of more importance in electric powered pumping equipment than any other type. Power costs are directly affected by power requirements of the installation. More efficient equipment means smaller motors with a resulting lower cost of operation.

The following example can best show what higher efficiencies mean to power costs.

Example of Costs

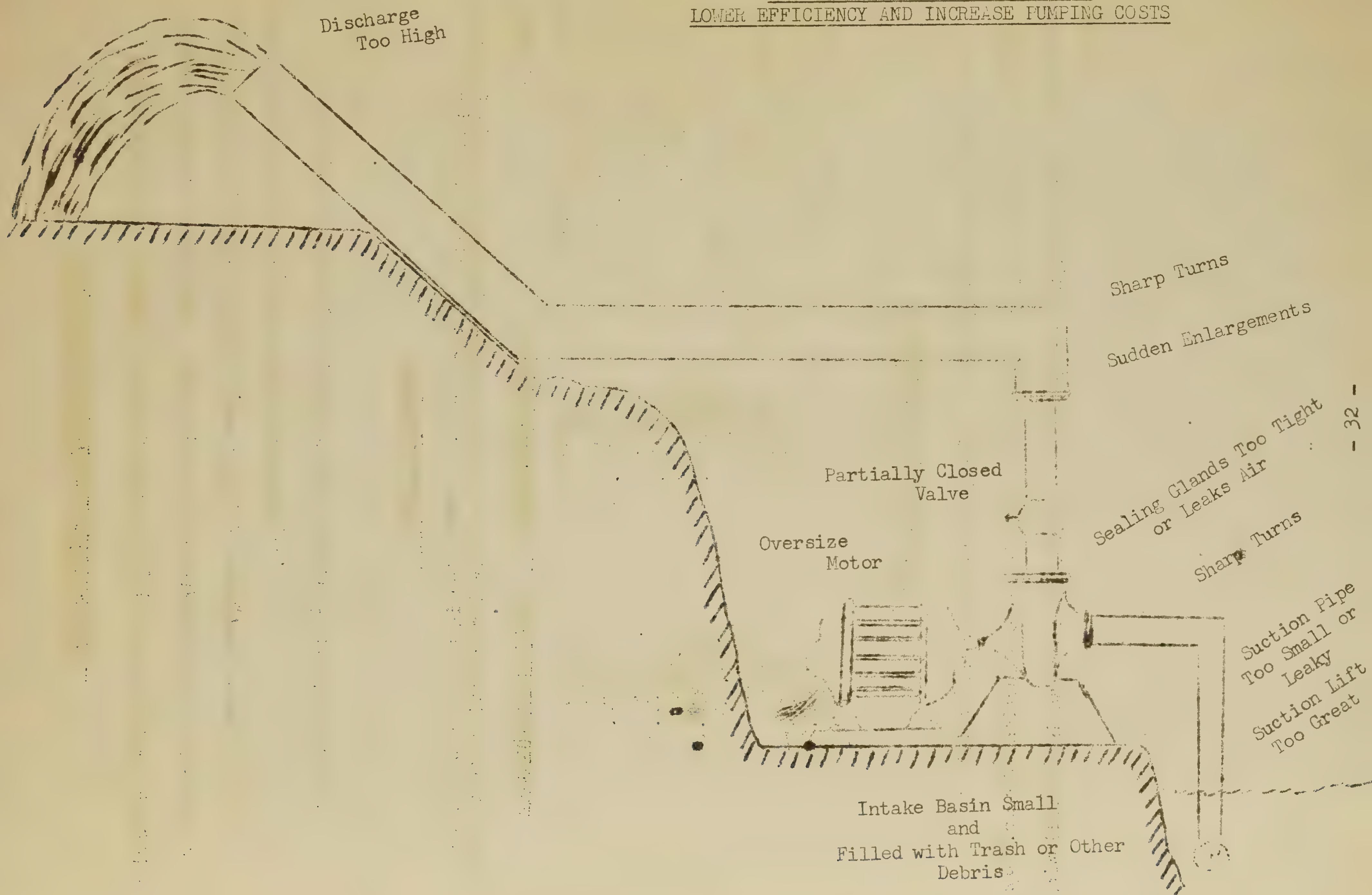
A pump efficiency test report where a pumping installation was overhauled showed the following improvements and actual cash savings to the farmer.

Plant	Before Overhauling	After Overhauling
Overall Plant Efficiency	32.1%	60
Water Pumped, gpm	730	730
Total Lift, Ft.	72.3	72.3
Motor Size, hp	40	20
Motor Input, hp	41.4	22.2
Kilowatt-hours	50,900	27,300
Power Cost	$726.30	$376.10
Hours Operated Per Year	1,647	1,647
Acre Feet Pumped Per Year	222	222
Kwhr per acre ft.	229	123
Cost Per Acre Foot	$3.27	$1.69
Saving in Power Costs		$350.20
Saving in Percent		48.0%

CONDITIONS WHICH MAY LOWER INSTALLATION EFFICIENCIES

There are many conditions which can greatly lower the efficiency of a pump irrigation installation. This is in addition to selection of pump. Some of the most common which can and should be avoided are shown in the following sketch.

A FEW COMMON CONDITIONS WHICH LOWER EFFICIENCY AND INCREASE PUMPING COSTS



________________________ Electric Cooperative, Inc.

____

Pump Test Report

Date ____________________
Member's Name ________________________ Address ______________________________

Equipment

Meter No. _______________
Motor ___________________ H.P. _________ Volts _________ Rated RPM _____________
Pump ____________________________ Type _______________ Drive __________________

Test Results

Total Operating Head

Water Level Below Center of Pump ________ Feet
Discharge Level or Highest Point of Elevation of Water Above Center of Pump ________ Feet
Friction Head ________ Feet

Total Operating Head ________ Feet

Water Pumped

Discharge ________ GPM

Water Horsepower

Water H.P. $= \frac{\text{GPM x Head}}{3960} = \frac{\_\_\_\_ \text{ X } \_\_\_\_}{3960} =$ ________ HP

Input to Motor

Disk Revolutions __________ Time __________ sec. K^h ________

KW input $= \frac{\text{R x K x 3.6}}{t} = \frac{\_\_\_\_ \text{ X } \_\_\_\_ \text{ x 3.6}}{t} =$ ________ KW Input

HP = KW input x 1.34 ________ x 1.34 = ________ H.P. Input

Overall Efficiency

Overall Efficiency $= \frac{\text{Water Horsepower Output}}{\text{Horsepower Input}} =$ ______ = ________ %

Miscellaneous Data

Yield of Well (GPM per foot drawdown) ________ GPM/ft.
Water Pumped 24 hours $= \frac{\text{GPM}}{450} =$ x2 ________ ac. ft.
Temperature Water ________ °F.
Measured Speed ________ RPM
Kilowatt Hours/Ac. Ft. of Water Pumped ________ kwh
kwh $= 1.024 \times \frac{\text{Total Head}}{\text{Overall Efficiency}} = 1.024 \times$ ________ = ________ kwh/ac.

PART III

L O A N A P P L I C A T I O N S
R A T E S
C O N T R A C T A G R E E M E N T S

Determining Pumping Costs

SUGGESTED PROCEDURE FOR PROVIDING ELECTRIC SERVICE TO IRRIGATION INSTALLATIONS

To provide electric service to an irrigation applicant it requires that funds for construction be made available, that certain agreements be executed with the applicant and that rate schedules for irrigation be established. The following information is provided to help expedite these requirements.

Preparation of Loan Application

On loan applications to REA which include service to irrigation installations it is necessary that additional information be provided on the irrigation installations. This additional information should be tabulated and consists of the following:

Item 1 - Detail Map No.
Item 2 - Irrigation Applicants' Names and P. O. Addresses
Item 3 - Signed Application
Item 4 - Acres To Be Irrigated
Item 5 - Est. Size of Load (HP)
Item 6 - Annual Guarantee
Item 7 - Est. of Annual Kilowatt Consumption
Item 8 - Est. of Annual Revenue

To secure the additional information the following steps of procedure are recommended. All forms shown are suggested forms.

Step I Whenever a request is made to the borrower for service to an irrigation installation the attached "Application For Irrigation Service and Membership" would be executed by the applicant.

Step II The attached Form AL-113, "Estimating Power Requirements For Electric Pump Irrigation Installations," will be completed at the same time the application is made in Step I. This will provide accurate estimates of Power Requirements of Installation and should be attached to and made a part of the applicant's application.

Step III When submitting a loan application, data secured in Steps I and II will be used in the preparation of the attached "Loan Application Tabulation For Pump Irrigation Installations."

This tabulation will be submitted with other tabulations, maps, board resolutions and additional data required to make a complete Loan Application.

Step IV Upon notice that funds are available to the borrower from REA or prior to the borrower starting construction to serve the applicant, the "Agreement For Electric Service To Irrigation Pump" (Form MA-162), as agreed to in the application, should be executed between applicant and borrower. Agreement would be retained by borrower.

SAMPLE

APPLICATION FOR IRRIGATION SERVICE AND MEMBERSHIP

The undersigned (hereinafter called the "Applicant") hereby applies for service for an irrigation installation and agrees to purchase electric energy from ____________________Inc. (hereinafter called the "Association") upon the following terms and conditions:

1. The Applicant will pay to the Association the sum of $__________, as a development fee, which, if the Applicant is not a member of the Association, will constitute his membership fee. The Applicant expressly agrees that the Association may, prior to the acceptance of this application, use the $_________in the development for extension of service to the Applicant's irrigation installation. If the Association is unable to obtain a loan from the Rural Electrification Administration to finance the construction to provide service, the Applicant agrees that only so much of the $________as has not been expended for development expenses will be returned to him. If the Association provides service to the irrigation installation, the sum of $_________will be retained by the Association.

2. The Applicant when assured that funds are available to provide electric service, will, within ______days, execute with the Association an "Agreement For Electric Service To Irrigation Installation." Applicant will pay for energy used according to rate schedule which will be attached and made a part of the Agreement. Notwithstanding any provision of the schedule, however, and irrespective of Applicant's requirements, the Applicant will pay to the Association not less than $_________per year for service or for having service available during the term of the agreement.

3. The Applicant will cause his installation to be wired in accordance with wiring specifications approved by the Association. The point of proposed service is approximately _______ feet from the proposed distribution line of the Association, or from the road.

4. The Applicant will comply with and be bound by the provisions of the charter and by-laws of the Association, and the agreement shall continue in force for thereafter or until cancelled by at least 30 days' written notice given by either party to the other.

Dated_______________________19____

____
Applicant

Witness___________________________

____
Post Office Address

Description Land and Well

Irrigation Application Data Sheet Attached. Map Reference ____________________

___________acres located on ___________side of __________road approximately

______________________________miles N-E-S-W from _________________________

Owner _____________________________Address _____________________________

Note: This application is for discussion purposes only. If it is to be used, it should first be reviewed by the borrower's attorney.

FORM AL-113
(8-51)

ESTIMATING POWER REQUIREMENTS FOR ELECTRIC PUMP IRRIGATION INSTALLATION

SYSTEM DESIGNATION: Colorado 00 Fisk

DATE: August 15, 1951

A. APPLICANT FOR IRRIGATION SERVICE

1A. NAME: Bert C. Cooke	1B. ADDRESS: Williston, Colorado
2A. LOCATION: T 16 S R 4 E SEC. 8	2B. MAP NUMBER: 121

3A. EXISTING INSTALLATION: Yes	3B. YEARS OPERATION: 4	4. PRESENT POWER SOURCE (*Diesel-Gas-etc.*): Gasoline Engine

B. WATER SUPPLY

1A. SOURCE (*Underground-surface*): Underground	1B. NAME (*Basin-river-etc.*): West Fork Basin
2A. DISCHARGE IN GALLONS PER MINUTE (*GPM*) EXISTING OR ANTICIPATED 900 GPM	2B. DISCHARGE IN ACRE INCHES PER HOUR 900 GPM X .0022 1.98 AC-IN/HR.

C. OPERATING HEAD

INSTRUCTIONS: TOTAL OPERATING HEAD IS THE ACTUAL WATER LIFT PLUS DISCHARGE HEAD IN FEET PLUS ALL OTHER RESISTANCE TO FLOW (*Pipe friction-elbows-valves-etc.*) IN FEET OF HEAD.

1. *SURFACE DISTRIBUTION* INSTRUCTIONS: SHOW WATER LIFT ONLY UNLESS CONSIDERABLE OTHER RESISTANCE IS PRESENT.

FROM WATER LEVEL (*During pumping*) TO CENTER OF PUMP DISCHARGE PIPE . . . . . 85 FEET

OTHER HEAD IN FEET (*Pipe friction-valves-etc.*) . . . . . ______ FEET

TOTAL OPERATING HEAD. . . . . 85 FEET

2. *SPRINKLER DISTRIBUTION* INSTRUCTIONS: DATA ON HEAD FOR SPRINKLER SYSTEM CAN BE OBTAINED FROM ENGINEER DESIGNING SPRINKLER SYSTEM.

FROM WATER LEVEL (*During pumping*) TO HIGHEST POINT OF WATER ELEVATION. . . . . ______ FEET

OPERATING SPRINKLER PRESSURE ______ LBS./SQ. IN. X 2.31. . . . . ______ FEET

OTHER HEAD IN FEET (*Pipe friction-valves-elbows-etc.*). . . . . ______ FEET

TOTAL OPERATING HEAD . . . . . ______ FEET

D. HORSEPOWER REQUIREMENTS

INSTRUCTIONS: ON NEW PUMP INSTALLATIONS OR ON INSTALLATIONS IN SERVICE FOUR YEARS OR LESS ASSUME A 60 PERCENT PUMP EFFICIENCY. ON INSTALLATIONS IN SERVICE OVER FOURS ASSUME A 50 PERCENT PUMP EFFICIENCY.

$$H.P. = \frac{\text{DISCHARGE GPM (Shown in B-2A) X HEAD (Shown in C)}}{\text{3960 X (Assumed pump efficiency)}} = \frac{900 \times 85}{3960 \times .60} = 32 \text{ H.P.}$$

E. KILOWATT REQUIREMENTS

INSTRUCTIONS: WHEN H.P. REQUIREMENTS OR DETERMINED TO BE 15 H.P. OR LESS ASSUME A 80 PERCENT MOTOR EFFICIENCY. WHEN DETERMINED TO BE OVER 15 H.P. ASSUME A 90 PERCENT MOTOR EFFICIENCY.

$$KW. = \frac{\text{H.P. (Shown in D) X .746}}{\text{(Assumed motor eff.)}} = \frac{32 \times .746}{.90} = 27 \text{ KW.}$$

INSTRUCTIONS: ASSISTANCE IN COMPLETING F, G AND H MAY BE OBTAINED FROM COUNTY AGENT, SOIL CONSERVATION SERVICE, OTHER IRRIGATOR OR SOMEONE FAMILIAR WITH THE IRRIGATION PRACTICES IN THE AREA. SOME FIELD ESTIMATES MAY BE REQUIRED.

F. CROP WATER REQUIREMENTS

CROP	CROPS TO BE IRRIGATED	AVERAGE ACRES TO BE IRRIGATED EACH SEASON	AVERAGE INCHES WATER REQUIRED FOR ONE WATER APPLICATION *(Include losses)*	HOURS PUMPING PER CROP PER WATER APPLICATION $\frac{\text{ACRES X IN. WATER REQUIRED}}{\text{DISCHARGE IN ACRE IN/HR. (B-2)}}$
(A)	Alfalfa	30	6	$\frac{30 \times 6}{1.98} = 91$
(B)	Pasture	20	5	50
(C)	Sugar Beets	20	5	50
(D)	Grains	10	4	20
(E)				
(F)				

G. NUMBER OF WATER APPLICATIONS DURING SEASON BY MONTHS

INSTRUCTIONS: IF CROP (A) IN F IS TO BE IRRIGATED ONCE IN MAY, ONCE IN JUNE, TWICE IN JULY AND TWICE IN AUGUST THEN OPPOSITE (A) YOU WOULD PLACE A 1 IN EACH COLUMN HEADED MAY & JUNE AND A 2 IN EACH COLUMN HEADED JULY & AUGUST. DO THIS FOR ALL CROPS SHOWN IN F.

CROP	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
(A)					1	1	2	2				
(B)				1	1	1	2	2	1			
(C)				1		1	2	2	2			
(D)				1	1	1						
(E)												
(F)												

H. NUMBER OF HOURS OF PUMPING DURING SEASON BY MONTHS

INSTRUCTIONS: NUMBER OF APPLICATIONS SHOWN IN G MULTIPLIED BY HOURS OF PUMPING PER CROP APPLICATION AS SHOWN IN F.

CROP	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
(A)					91	91	182	182				
(B)				50	50	50	100	100	50			
(C)				50		50	100	100	100			
(D)				20	20	20						
(E)												
(F)												
TOTAL				120	161	211	382	382	150			

I. TOTAL KILOWATT-HOUR CONSUMPTION DURING SEASON BY MONTHS

INSTRUCTIONS: KILOWATT HOURS = kw *(Shown in E)* X HOURS *(Shown in H)*

MONTH	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
KWH				3,240	4,347	5,697	10,314	10,314	4,057			

TOTAL KILOWATT-HOUR CONSUMPTION FOR SEASON: 37,969

IRRIGATOR INTERVIEWED BY

FORM AL-58A
(11-51)

U.S. DEPARTMENT OF AGRICULTURE
RURAL ELECTRIFICATION ADMINISTRATION

PUMP IRRIGATION SURVEY TABULATION

Budget Bureau No. 40-R2358
Approval Expires October 31, 1953

SYSTEM DESIGNATION
Colorado 00 Fisk

DATE
August 15, 1951

To: U.S. DEPARTMENT OF AGRICULTURE, REA, WASHINGTON 25, D.C.
Attention: APPLICATIONS AND LOANS DIVISION

INSTRUCTIONS: SEE LOAN AND POWER USE MEMORANDUM NO.3

DETAIL MAP NO.	MEMBER'S NAME AND POST OFFICE ADDRESS	SIGNED APPLI-CATION		EASEMENTS SIGNED		ACRES TO BE IRRI-GATED	SIZE OF LOAD (*HP*)	ESTIMATED KWH YEAR	ANNUAL GUARANTEE	ESTIMATED ANNUAL REVENUE
		YES	NO	YES	NO					
121	Bert C. Cooke Williston, Colorado	X		X		80	35	37,969	$280.000	$759.38
133	Jack Fryer Williston, Colorado	X		X		64	20	15,240	160.00	360.40
155	John Jones Manchester, Colorado	X		X		120	40	44,880	400.00	897.60
	Complete Irrigation Tabulation For All Irrigation Installations Included In Application									
	TOTAL									

DATE

CERTIFIED BY (*Secretary of Cooperative*)

Form CO-199
(12-51)

AGREEMENT FOR ELECTRIC SERVICE TO IRRIGATION PUMP

AGREEMENT made ______________________________, 19____, between ____(hereinafter called the "Seller") and ______________________________________ (hereinafter called the "Consumer").

WHEREAS, Seller will have electric power and energy available for sale at Consumer's premises as soon as certain electric lines and facilities are constructed.

NOW, therefore, this agreement,

WITNESSETH:

The Seller agrees to sell and deliver to the Consumer, and the Consumer agrees to purchase and pay for electric power and energy sufficient to operate a____________________horsepower irrigation pump motor at the location hereinafter described, upon the following terms:

1. Service Characteristics

a. Service hereunder shall be alternating current, ___________ phase, sixty cycles, ________volts.

b. The Consumer agrees not to use the electric power and energy furnished hereunder as an auxiliary or supplement to any other source of power and that electric power and energy purchased hereunder will not be resold.

2. Payment

a. Consumer shall pay the Seller for service hereunder at the rates and upon the terms and conditions set forth in Schedule _____attached to and made a part of this agreement. Notwithstanding

any provision of the Schedule, however, and irrespective of Consumer's requirements, the Consumer shall pay to the Seller not less than $____________per year for service or for having service available hereunder during the term hereof, provided, however, that Seller shall make available electric power and energy hereunder on or before ______________, 19___.

b. The initial monthly billing period shall start when Consumer begins using electric power and energy, or at the time of commencement of the irrigation season next following the date Seller first makes service available to Consumer hereunder, whichever shall occur first; provided, however, that if said initial monthly billing period starts after the commencement of the normal irrigation season the foregoing yearly minimum charge shall be prorated on the basis of the ratio that the number of months service is available or furnished hereunder during the initial normal irrigation season bears to the number of months in said irrigation season.

c. Bills for service hereunder shall be paid at the office of Seller in ____________________, State of ______________, monthly within ten (10) days after the bill is mailed to the Consumer. If Consumer shall fail to pay any such bill within such ten (10) day period, Seller may discontinue service hereunder by giving ten (10) days' notice in writing to Consumer.

3. Membership

The Consumer shall become a member of the Seller, shall pay the membership fee and be bound by the provisions of the articles of incorporation and by-laws of the Seller and by such rules and regulations as may from time to time be adopted by the Seller.

4. <u>Right of Access</u>

Duly authorized representatives of Seller shall be permitted to enter Consumer's premises at all reasonable times in order to carry out the provisions hereof.

5. <u>Continuity of Service</u>

The Seller shall use reasonable diligence to provide a constant and uninterrupted supply of electric power and energy; but if such supply should fail or be interrupted, or become defective through act of God, governmental authority, action of the elements, public enemy, accident, strikes, labor trouble, required maintenance work, inability to secure right of way, or any other cause beyond the reasonable control of Seller, Seller shall not be liable under the provisions of this agreement.

6. <u>Term</u>

This Agreement shall become effective on the date first above written, and shall remain in effect for a period of ______ years and thereafter from year to year until terminated by either party giving to the other ____________ months' notice in writing.

IN WITNESS WHEREOF, the parties hereto have executed this agreement as of the day and year first above written.

____
Seller

Attest:

By______________________________
President

____
Secretary

____
Consumer

LAND DESCRIPTION AND LOCATION OF WELL

__________ acres located on ______ side of __________ road

approximately ______________ miles N-E-S-W from __________

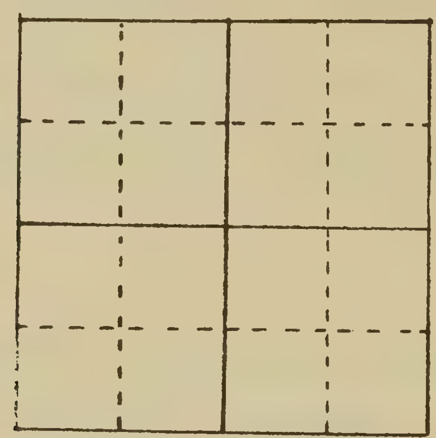
Section ______________ Township ___________ Range ________

Owner ____

Address ____

(Spot your well in the 40-acre tract of the section below).

N

W  E

S

IRRIGATION RATES

Introduction

There has been a lack of understanding in regard to the design of the various pump irrigation rate schedules in effect. It is, therefore, felt that the following discussion prepared by REA Rate Section on irrigation rates will be useful.

Cost Elements

Any cooperative which serves an appreciable number of irrigators will have a heavy investment in transformers and service lines for irrigation. It must also build heavier, more expensive distribution lines and substations than would otherwise be necessary. Revenue from irrigators should cover the increase in expenses arising from this increased plant investment, in addition to cost of power purchased for irrigation. It is desirable to keep the irrigation rate as low as possible without subsidizing irrigation by revenue from other consumers. Therefore, irrigation rates for REA systems are designed to cover these "incremental" costs, but not a full share of system overhead expenses.

The cooperative's cost of wholesale power for irrigation will, of course, vary with the KWH and KW used by the irrigators. All other expenses of irrigation service - interest, amortization, taxes, insurance, operation, maintenance, and reserve for replacement, will remain fairly constant depending on the total plant investment for providing service to irrigators, and may be referred to as "Fixed costs." Each individual irrigator's equitable share of the total fixed costs is proportional to the size of his pumping load in horsepower regardless of his KWH usage. Fixed costs may thus be reduced to an amount per connected horsepower of motor load.

It is important that the irrigation rate be designed to recover fixed costs, whether the irrigator's KWH usage in relation to horsepower (which depends on total hours pumping) is great or small, and during years when an irrigator needs little or no irrigation, it is important that he be required to pay a minimum charge to cover a sufficient portion of his share of fixed costs.

Rates

Because of the seasonal nature of their requirements, it is necessary to design special types of rates for service to irrigators rather than use the standard type of farm or power rate. Another aspect of a good irrigation rate is that the average rate per KWH should decrease as the irrigator's number of hours pumping increases, to an extent which will encourage the irrigator to pump more hours and use the smallest motor possible. Good overall utilization of the plant investment makes a lower average rate feasible for a smaller motor pumping more hours.

A workable irrigation rate which best meets the requirements discussed above, is the type illustrated in the attached exhibit A, a sample irrigation rate schedule. This rate includes a charge per connected horsepower per year and an energy charge. The horsepower charge is a fixed charge which does not entitle the irrigator to the use of energy, and is also the minimum annual charge. It is a charge based on the individual irrigator's share of fixed costs, which depends on the horsepower of the motor served. There is a margin above power costs in the energy charge which will cover part of the fixed costs, but the horsepower charge should cover no less than the fixed costs incident to the irrigator's transformers and service installation.

This type of irrigation rate consisting of a horsepower charge, plus an energy charge, permits the lowest possible annual minimum charge, since no energy is included for the fixed charge, and the entire amount goes towards meeting the cooperative's fixed costs of supplying service. If the horsepower charge included the use of energy, or if the rate consisted of charges per KWH only, the minimum would have to be high enough to cover, in addition to fixed costs, the cost of power to which the irrigator would be entitled for the amount of the minimum. This would be necessary protection to the cooperative even though it would penalize the irrigator during years when he did little or no irrigating.

Very often when an irrigation rate including a horsepower charge is introduced on a cooperative, there is considerable consumer resistance to the horsepower charge because no energy is included. The uninformed irrigator feels that he should pay only on the basis of the KWH he needs. He must be made to understand, as a member of the cooperative, that the cooperative incurs considerable, continuing expense simply to provide him with service, even though he may not use one KWH; and that the horsepower charge assures his cooperative of meeting these expenses. On the other hand, he should understand that the horsepower charge permits a lower minimum bill. This is important to him during years when little or no irrigation is required. Accordingly this type of rate is particularly advantageous to irrigators in areas where little or no irrigation is necessary in wet years.

Two other types of rates commonly used for irrigation are shown in Exhibit B. These rates require a higher annual minimum, since they consist only of energy charges, so that an allowance for cost of power must be included in the minimum. Fixed costs are recovered in the higher priced energy blocks. The size of these blocks is based on connected horsepower of motor load, so that, indirectly, the same effect is obtained as with a rate including a horsepower charge - fixed costs are covered on the basis of horsepower load, and the irrigator is encouraged to pump longer hours and thus earn a lower average rate per KWH.

The minimum charge should be on an annual basis under any irrigation rate, but the energy charges may be on a monthly basis, as illustrated in one of the Exhibit B rates. This has some advantage if the cooperative's rate for purchased power includes a demand charge, in that additional irrigation revenue is obtained during the specific months that the irrigation load increases the demand charge in the wholesale power bill. In other respects, an annual rate is more appropriate to the annual cycle of irrigation.

Overall revenue under an annual rate can be quite accurately estimated for any amount of average consumption per irrigator per year, but under a monthly rate, the revenue for a particular annual average usage will be more dependent on variation in consumption from month-to-month and between consumers. A monthly rate designed to average the same cost per KWH as an annual rate under normal pumping might produce appreciably less revenue than the annual rate during an unusually short pumping season.

It has been emphasized throughout the above discussion that the cooperative is burdened with the fixed costs of supplying irrigation service regardless of the amount of pumping. Fixed costs continue from year to year, even though irrigation service may not be used in some years. It is therefore important that the cooperative obtain at least the minimum bill revenue from each irrigator year in and year out. Irrigation contracts for a one year period do not give adequate protection in this respect. Any member who wants irrigation service should therefore be required to sign a contract for at least a three year period (preferably five) which contains adequate provisions regarding payment of the minimum each year, and a provision that the contract shall automatically be renewed for like periods unless notice of termination is given before an expiration date. In the absence of such contract provisions, the cooperative can make rules for irrigation service which accomplish the same purpose by requiring payment of the minimum every year. However, it is best to incorporate these requirements in a contract.

Summary

To sum up:

1. A separate fixed charge per horsepower makes possible a low annual minimum charge.

2. The minimum charge must be paid every year, even though service is not used.

3. Rates for irrigation should be so designed that there is a strong incentive for the irrigator to install a motor of minimum size and pump a maximum number of hours.

4. REA irrigation rates are designed on an "incremental cost" basis which results in a preferential rate but not a rate so low that irrigators are subsidized by other consumers.

Exhibit "A"

SCHEDULE 1
IRRIGATION SERVICE

Availability

Available to members of the cooperative located adjacent to its three-phase lines for pump irrigation service, subject to the cooperative's established rules and regulations, where the member has signed a contract for at least three years.

Type of Service

Three-phase, 60 cycle, at available secondary voltage.

Rate

A Fixed Horsepower Charge of $6.00 per horsepower per year.
Plus:
Energy Charge of 1.5¢ per KWH for all energy used.

Minimum Annual Charge

The minimum annual charge under the above rate shall be $6.00 per horsepower, except that for motors of less than 10 HP it shall be $60.00.

Determination of Horsepower

The horsepower for billing purposes shall be the motor nameplate rating, or at its option the cooperative may determine the horsepower by test under conditions of maximum operating load. The horsepower is subject to adjustment for power factor, as follows:

Power Factor

The consumer agrees to maintain unity power factor as nearly as practicable. The horsepower for billing purposes may be adjusted to correct for average power factors lower than 90%, if and when the Seller deems necessary. Such adjustments will be made by increasing the horsepower 1% for each 1% by which the average power factor is less than 90% lagging.

Terms of Payment

All of the above rates are net, the gross rates being five percent (5%) higher. In the event the current monthly bill is not paid within fifteen (15) days from the date of the bill, the gross rates shall apply. The horsepower charge shall be due and payable in three equal installments on the ________ day of ____________, ____________, and ________ each year.

EXHIBIT "B"

The following rates were designed as alternates to the rate incorporated in Exhibit "A", based on the same basic data.

1. Annual rate without horsepower charge:

First	500	kwh per hp per year @ 2.5¢ per kwh
Next	500	kwh per hp per year @ 1.75¢ per kwh
Over	1000	kwh per hp per year @ 1.5¢ per kwh

2. Monthly rate without horsepower charge:

First	50	kwh per hp per month @ 3.0¢ per kwh
Next	50	kwh per hp per month @ 2.0¢ per kwh
Over	100	kwh per hp per month @ 1.5¢ per kwh

Minimum Annual Charge: - $10.00 per hp

EXAMPLE METHOD OF DETERMINING COSTS OF PUMPING FOR IRRIGATION

The following example has been prepared to show a method to itemize and determine irrigation pumping costs. Costs are usually expressed in dollars per acre-foot, as shown in the following example.

Electric Motor - Direct Connect

1.	Operating Conditions		
	a. Water Pumped	100 Ac. Ft.	
	b. Capacity of Pump	900 G. P. M.	
	c. Total Pumping Head	92 Feet	
	d. Hours of Operation	600 Hours	
	e. Pump Efficiency	70 Percent	
	f. Horsepower Input to Motor	30 H.P.	
	g. Kilowatt Input to Motor	24.8 KW	
	h. Motor Efficiency	90 Percent	
	i. Horsepower Rating of Motor	30 H.P.	
2.	*Investment in Plant		
	a. Well (Drilling - Casing - Testing)		$1125.00
	b. Pump (Column Pipe - Strainer - Pump Head - Etc.)		1500.00
	c. Power Transmission (Direct) (Belts)		
	d. Power Unit With All Respective Appurtenances		950.00
	e. Plant Housing and Lay out		125.00
	f. Installation		75.00
			$3775.00
3.	Fixed Charges		
	a. **Interest — $1887.50 @ 6%	113.25	
	b. **Taxes & Insurance — $1887.50 at 2%	37.75	
	c. Depreciation — $3775.00 @ 5% (20 Years)	188.75	
	Total Fixed Charges	$339.75	
4.	Operating Charges		
	Energy Consumption	14,880 kwh.	
	a. Energy charges		
	H.P. charge 30 x $6.00 =	$180.00	
	3000 kwh @ 2¢ =	60.00	
	6000 kwh @ 1.5¢ =	90.00	
	5880 kwh @ 1.0¢ =	58.80	
	Total Energy Charges		$ 388.80
	b. Lubricants 100 ac. ft. x 0.05/ac Ft.		5.00
	c. Repairs 100 ac. ft. x 0.20/ac Ft.		20.00
	d. Attendance		— —
	Total Operating Costs		$ 413.80
5.	Recapitulation		
	Fixed charges	339.75	
	Operating charges	413.80	
	Total Annual Costs		$ 753.55
	Costs of Pumping per Acre Foot		7.53

*Prices used for illustrative purposes only.
**Average Investment Over a Period of Years.

PART IV

PROPOSED A.S.A.E. MINIMUM REQUIREMENTS
Design, Installation, and Performance

of

Sprinkler Irrigation Equipment

These minimum requirements pertain to the design, installation, and performance of sprinkler irrigation equipment, and include dealer-purchaser responsibilities. The design and performance requirements are concerned particularly with those factors that are directly related to land, crops, and farm operations. The dealer-purchaser responsibilities recognize successful operation of a sprinkler system as depending on both buyer and seller.

The following requirements were proposed by the American Society of Agricultural Engineers and accepted by the Sprinkler Irrigation Equipment manufacturers and distributors.

DESIGN AND PERFORMANCE

1. Application Rate

A portable sprinkler irrigation system, when properly designed and operated, shall meet the following conditions with respect to water application:

(a) Apply water at a rate which does not cause runoff during the normal operating period nor cause water to stand on the surface of the ground after the sprinkler line is shut off.

(b) Determination of the proper rate of application shall be the responsibility of the person designing the system. Values for bare ground infiltration rates for different types of local soils may be obtained from responsible agricultural technicians. In the absence of such technical advice, the designer may estimate the proper application rate on the basis of past experience with similar soil types.

2. System Capacity

(a) For regularly irrigated areas, the system shall have the capacity to meet the peak moisture demands of each and all crops irrigated within the area for which it is designed. Sufficient time must be allowed for moving laterals and for permitting cultural practices on the land. The capacity must also allow for reasonable water losses during application periods with the system operating in accordance with design conditions.

(b) For supplemental irrigation and/or special uses, the system shall have the capacity to apply stated amount of water to the design area in a specified net operating time period.

3. Depth of Water Application

In the design of the system, total depth of application (equivalent rainfall) per irrigation shall be governed by the capacity of the soil for moisture storage and the depth of the principal root zone of the crop irrigated. Information on both of these factors may be obtained from agricultural technicians or may be estimated by the designer on the basis of his past experience with similar soil types and crops.

4. Uniformity of Water Application

Uniformity of water application is affected by both pressure in the line and spacing of sprinklers. Recommendations for desirable operating pressures and spacings for different types of sprinklers and nozzle sizes should be obtained from the sprinkler manufacturer.

Differences in pressures at the sprinklers should be kept to a minimum to assure reasonably uniform distribution of water over the entire design area. A common rule, which should be adhered to as closely as practicable, is to limit pressure differences along a sprinkler lateral to 20 percent of the higher pressure.

Excessive pressure differences in the main or supply line result in widely varying pressures at the head of the laterals. In many instances these excessive variations cannot be controlled by pipe size alone. Then the only practical alternative is to design for adequate pressure at the lateral take-off where pressure in the main will be lowest and instruct the operator in regulating pressures into the other laterals by adjusting the take-off valve openings.

5. Crop Damage

Water must be applied in a manner which will not cause direct physical damage to plants or fruit.

DEALER-PURCHASER RESPONSIBILITIES

1. Dealer Responsibility

(a) Proper Design

When the system is planned by a dealer, or his representative, the dealer assumes full responsibility for the proper design of the system he proposes to furnish. Design requirements to fit the system to conditions of soil, topography, water supply and crop enterprise must be ascertained by the dealer either directly or by obtaining such information from recognized reliable sources.

When design requirements are furnished in writing by the purchaser, the dealer's responsibility is limited to the design of the system to meet the stated conditions.

When plans and specifications are furnished in writing by the purchaser, the dealer's responsibility is limited to supplying equipment which will satisfy the requirements of the specifications furnished.

When the purchaser buys the system piecemeal, he absolves all dealers of responsibility for the performance of the system as a unit.

(b) Proper Installation

The dealer or his representative assumes full responsibility for the proper installation of the system.

Pumps and power units must be set on a firm base and care must be taken to keep the pump and the motor or engine in proper alignment.

1. (b) Cont'd

Wiring and starting equipment for electrically operated plants must comply with approved standards. Electric motors must be provided with overload and low-voltage protection.

Internal combustion engines must be provided with protective devices. Thermostats must be supplied that stop the engine when water or oil temperatures exceed the safety point. Where conditions are such that a failure of the water supply might result in the pump losing its prime, the pumping plant must be protected by a device that stops the engine. These devices may be dispensed with where conditions are such that there is little probability of water supply failure, or when the pumping plant is constantly attended.

(c) Operating Instructions

The dealer or dealers furnishing equipment required for a complete sprinkler system should furnish to the purchaser, in writing, such instructions, performance charts and layout drawings as are required to insure proper operation, in accordance with design conditions and normal expected life for the type of equipment furnished.

(d) Performance Warranty

When a dealer or associated group of dealers assumes responsibility for the design and installation of a sprinkler irrigation system, a warranty should be furnished, stating specially the performance expected for water application rate, capacity, rate of coverage for a specific design area serving specific crops and crop acreages as stated by the purchaser and mutually understood to be the basis of design.

Warranty should be based on trial of the system during operation under the range of operating conditions imposed on the system. The warranty should not be expected to cover any conditions encountered which were beyond reasonable control of the dealer either in design or installation. Values used for infiltration rate, peak use rate of moisture by crops, or capacity of soils to retain water for plants cannot be expected to be accurate for every local condition of soil. Evidence that the dealer has made reasonable efforts to obtain values from reliable sources should be sufficient reason to absolve him from responsibility if such values do not represent local conditions.

When a dealer, or dealers, assumes responsibility for the installation of a system in accordance with specifications supplied by the purchaser, a warranty should be furnished, stating the performance expected as to friction loss in the system, pump and engine or motor characteristics and other pertinent data pertaining to the specifications.

(e) Equipment Warranty

The dealer or dealers assuming responsibility for the installation of the system must furnish warranties covering the quality of material and workmanship of each piece of equipment furnished in accordance with the original manufacturers guarantee, and provide for replacement of defective parts shown to have failed because of poor quality materials or poor workmanship.

(f) Maintenance and Repair Service

Dealers selling sprinkler irrigation systems in a territory should maintain an inventory of replaceable parts and required equipment repair service. The extent of this available service should be such that users in the territory would be assured of reasonable service which would avoid crop loss due to shutdown of a system for replacements or repairs.

2. Purchaser Responsibility

(a) Operations in Accordance With Instructions

The purchaser and user of a sprinkler irrigation system has to assume responsibility for failure of the system to perform properly if, after receiving all data furnished by the dealer, he fails to operate the system in accordance with all conditions assumed in the design of the system. To obtain a full life of all equipment the user must observe the stated limits of operating conditions set forth by the manufacturer.

(b) Care and Maintenance Recommendations

The purchaser must follow the dealer's recommendations for care and maintenance of the equipment. This applies to periods of use as well as non-use of the equipment.

DEFINITIONS

Design Area

The specific land area which the supplier or designer and the purchaser mutually understand will be irrigated by the sprinkler system.

Sprinkler Irrigation System

Includes all equipment required to apply water to the design area, from the source of water supplying the system to the revolving sprinkler, nozzles, or perforated pipe.

If water is already available to the design area, the system includes only the equipment required to develop the necessary pressure and apply the water to the area.

If both water and pressure are available, as in the case of an existing pressure line, the system includes only the equipment required to take water under pressure from the supply line and apply it to the design area.

Sprinkler Lateral

A line of portable pipe or tubing with sprinklers, nozzles, or perforations along the line. A lateral may be one of several operated from a common main supply line, or may be a single unit supplied directly from the water source.

Application Rate

The equivalent rainfall rate, expressed in inches of water depth per hour, (acre-inches per acre per hour). For systems with rotating sprinklers, the rate is computed on the basis of the spacing of lateral settings, the spacing of the sprinklers along the lateral, and the average discharge of the sprinklers. For perforated pipe systems, the application rate is computed from lateral spacings, length of lateral, and average flow into the lateral.

Infiltration Rate

The rate at which soil will take in water during the irrigation period; expressed in inches of water depth per hour (acre-inches per acre per hour).

Peak Moisture Demand

Peak moisture demand of any crop is considered to be the maximum that occurs during periods of maximum temperature and crop growth. This peak demand for moisture on the part of a crop results from transpiration by the plants, and direct evaporation from the soil.